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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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H.-Wolfg. Lahmann / M. Stöckmann

Optical Inspection of Cutting Tools by means of 2D- and 3D-Image Processing

Image Processing, Image Analysis and Computer Visions

ABSTRACT

2D-and 3D-image processing systems become more and more important in the cutting tool industry. Because of increased requirements to the different machining processes (e.g. milling, turning, grinding) the used cutting tools must have a very high quality. Hence, it is necessary to evaluate the tools quality before they are used in the machine. The non-contact determination of quality parameters by means of image processing systems is therefore of special relevance. This paper presents a solution of 2D-inspection of cutting inserts for hard-whirling processes and a 3D-measuring approach in order to evaluate features of the surface topography of grinding tools.

1 INTRODUCTION

The hard-whirling process is the most economical milling procedure for the production of threads and thread-like profiles. Hard whirling uses profiled cutting inserts which must be specially prepared.
The profiling of new and worn cutting inserts for whirling tools is realised by a grinding process. Before the grinding process can start the correct processing parameters for the machine are to be determined. For the determination of processing parameters the geometry (i.e. the contour) and the wear of already used cutting inserts are to be measured by means of a vision system. In the first part of this paper a developed solution will be presented to evaluate the profile and face wear of cutting inserts. In the second part two investigated measuring principles for the evaluation of surface topography features of grinding tools, which are used in profiling process of cutting inserts et al., will be described.

2 DETERMINATION OF WEAR FEATURES OF CUTTING INSERTS

In order to detect and to evaluate the wear appearances it is necessary to use incident lights for acquisition of face wear and transmitted light for acquisition of profile wear. Fig. 1 shows both applied measuring principles.

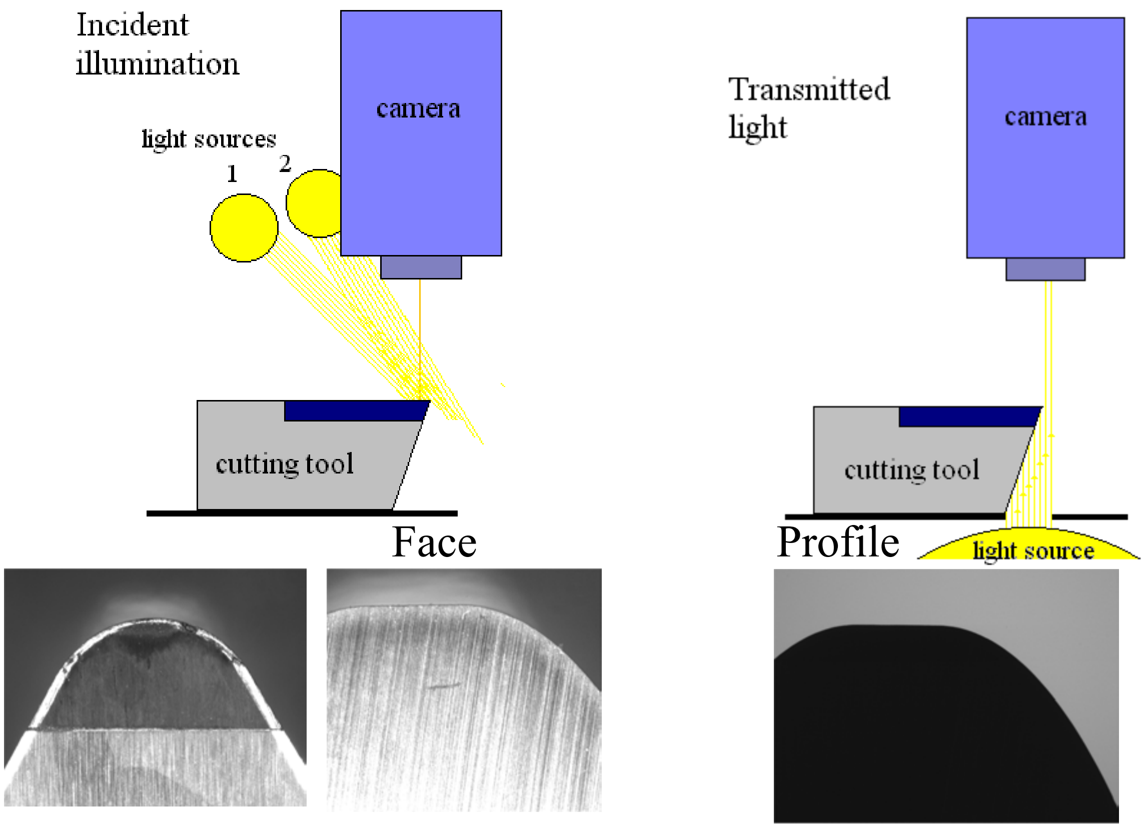


Fig.1: 2D-Measuring principles

For the detection of both kinds of wear appearances a coordinate measuring device with a high resolution CCD matrix camera and a special illumination unit are used. The measuring device is coupled to a computer system to control the grinding machine which profiles the tools to be used in the hard-whirling process. The incident illumination unit consists of two light sources which are aligned onto the focus of the camera system (Fig. 2). The light sources are automatically controlled by evaluating the contrast of the surfaces measured. Angles of the cutting surface can be measured to an accuracy of 2 degrees. This illumination allows image acquisition with reproducible quality and full contrast pictures. The separate radial and vertical positioning of the illuminator arms enables to light up any cutting face profiles for an evaluation.

On the basis of the dimension of cutting inserts some images of the cutting face are captured and fit together. This is based on the necessary magnification of the cutting face for the take up of the wear dimension. For this reproduction you need a 3 times magnification on the coordinate measuring device (UNI-VIS 250,Mahr OKM GmbH) with an appropriate image size of 2.44mm x 2.46mm. In relation to this image field you need 3 up to 12 pictures depending on the whirling blade (cutting insert) size. These images have to be taken up overlapped, with the same contrast /1/.

The determination of profile wear is carried out in transmitted light by means of 2D-image processing approach. At this principle the cutting edge of whirling insert is projected as bright/dark transition on the camera. The bright/dark transition is detected via measuring line, located perpendicular to the cutting edge, and as scatter-plot of measuring data is recorded. About the measured x-y-positions of coordinate table of measuring device in relation to the CCD-camera the data will be exactly related to each other and evaluated. The measuring process occurs fully automated on the basis of CAD files. The end result is the profile deviation between actual- und nominal contour /2/.

The face wear is captured in incident light (Fig. 2). After image acquisition of all single-regions of the insert surface the captured images are fit together in order to evaluate the surface wear (Fig. 3). Afterwards follows the calculation of wear in several steps. Based on the cutting edge the position of the chamfer is determined at first, if presented, and then it will be determined the areas of wear. The face wear is subdivided in breakouts as well as in width and depth of wear. The determination of depth of wear is carried out separately by means of a 3D-image processing approach (according to confocal principle) /3/.

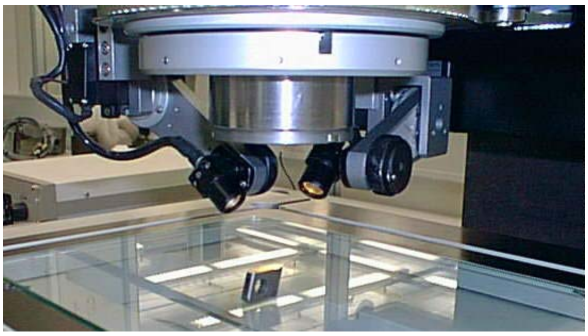


Fig. 2: Incident light source

(Source: Mahr OKM)

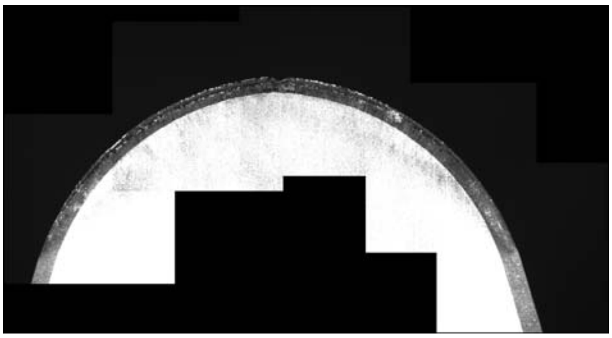
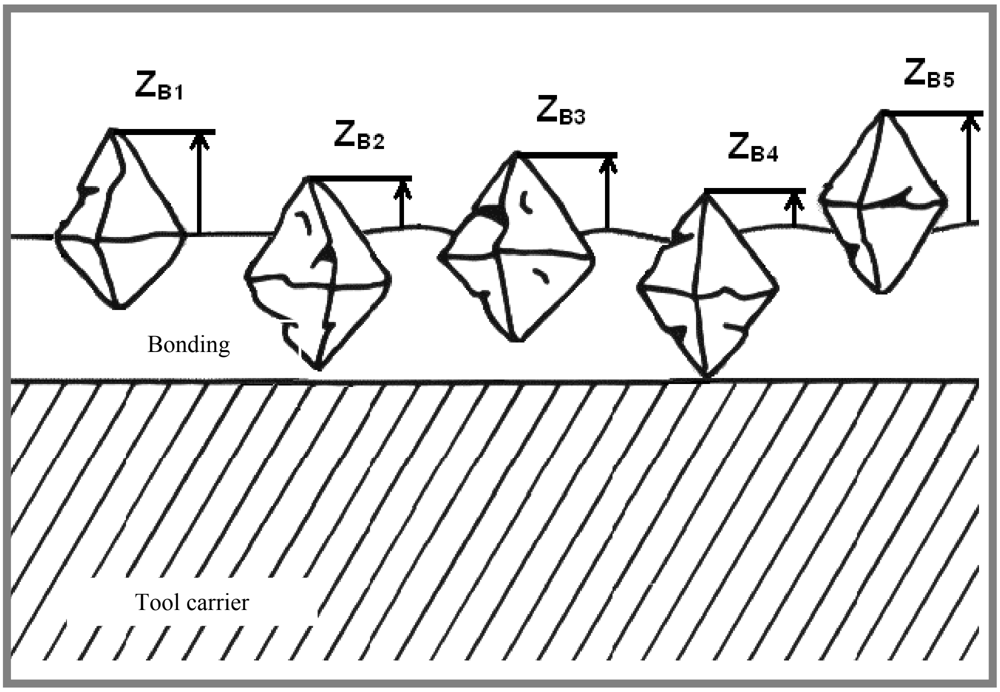


Fig. 3: Composed images

3 DETERMINATION OF SURFACE FEATURES OF GRINDING TOOLS

High precision and economical grinding of cutting tools as well as of workpieces can only be done by means of very sharp grinding tools. Therefore the topography of grinding tools plays a very high importance. Electroplated grinding tools (metal bonded grinding tools) have generally a single grinding layer. This thickness depends on the process of electroplating the grinding grains in the bonding matrix and reaches values between 30% up to 60% of the used grain size. The production process of electroplated grinding tools is determined by statistical procedures, which also influence the physical characteristics.

The key features for the topography of electroplated grinding tools are the average grain protrusion (Fig. 4) and the average deviation of the grain peaks. Based on a White-Light-Interferometer and a Confocal System with Super-Long-Working-Distance- Objectives 3D-image processing approach were investigated in order to determine the key features for the topography of grinding tools.



$$K_B = \frac{1}{N} * \sum_{n=1}^{N} z_{Bn}$$

Fig. 4: Average grain protrusion (K_B)

At the White Light Interferometry the short coherence length of white light source is used. A beam of white light is split. One beam is projected on the tool surface to be measured, the other is projected on reference mirror. After reflection at the surface, both beams recombine and interfere (correlogram, Fig. 5). A CCD-camera captures the local intensity created as function of the tool topography. Moving the grinding tool during the measurement changes the interference pattern, which allows the determination of maximal values of grain peaks and the bonding level. Based on this information a computer generates a 3D-image of the tool´s topography. Following the 3D-image is used in order to calculate the average grain protrusion and the average deviation of the grain peaks.

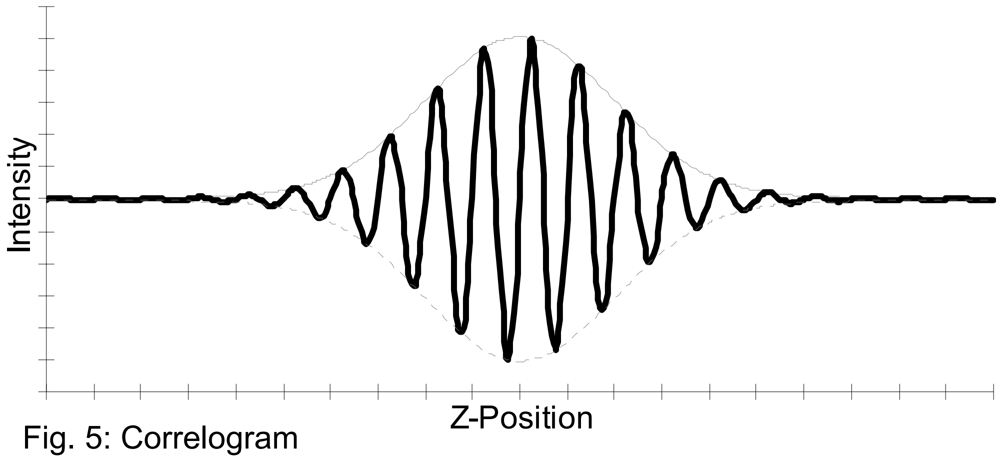


Fig. 5: Correlogram

At the Confocal System (Fig. 7) microscope objectives with high numerical apertures ($0.6 < N < 1.4$) and super-long-working-distance are used. The optical unit (camera, illumination) of the Confocal System is advanced vertically in steps so that each point on the tool surface passes through the focus. The focus function (contrast in depending of vertical position) is determined for each pixel of the CCD-camera. Then the maximum of each focus function is determined and out of it the 3D-image is generated (Fig. 6). The 3D-image data is the basis for the calculation of the average grain protrusion and the average deviation of the grain peaks /4/.

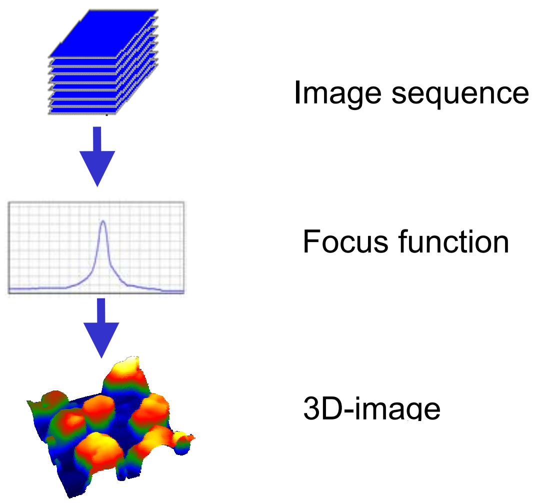


Fig. 6: Procedure

Fig. 7: Confocal System

Both the White Light Interferometry and the Confocal Microscopy may be used for the determination of the average grain protrusion and the average deviation of the grain peaks of electroplated grinding tools. The achieved results have shown that the topography of grinding tools with natural grains is better to detect by means of the Confocal Microscopy than by means of the White Light Interferometry. Investigations on grinding tools with synthetic grains showed good results based on the White Light Interferometry.

In consideration of required measuring time and accuracy of measurement by user of the industry the application of Confocal Microscopy is preferable compared to the White Light Interferometry.

4 Conclusion

The fundamental investigations for the development of 2D-inspection solution for cutting inserts were carried out in close co-operation with partners of tool and measurement equipment industry /1/.

The first development works in conjunction with the White Light Interferometry and the Confocal Microscopy were supported by companies of the grinding tool industry /5/.

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